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METHOD FOR THE MATURATION OF BEERBACKGROUND OF THE INVENTION

The present invention relates to a continuous method for the maturation of beer after main fermentation, in which method the unmaturred beer, after removal of yeast and a heat treatment, is passed into a bio-reactor filled with a carrier with yeast immobilised on it. The invention also relates to a continuous maturation reactor, which is an upright column-type flow-through reactor containing one or more sieves, intermediate floors or flanges and which is filled with a carrier with yeast immobilised on it.

Beer production generally comprises the following main steps:

- malting of grain (usually barley) by germinating,
  - crushing of the malted grain to produce malt grist,
  - adding water into the grist to form a mash,
  - mashing to decompose starch into fermentable sugar,
  - separating the wort thus produced from the mash,
  - cooking the wort with hops to produce a taste and aroma and to stop the enzymatic activity,
  - clarifying and cooling the wort,
  - fermenting the wort with yeast to convert the glucose and maltose into ethanol and carbon dioxide (main fermentation) to produce unmaturred beer,
  - maturing the unmaturred beer (secondary fermentation), and
  - filtering and stabilising the beer and putting it into suitable containers.
- The maturation of beer is an important operation to give the beer a mellow and homogeneous taste and flavour.

Traditionally, beer is matured by storing the unmatured beer for several weeks at a low temperature after the main fermentation. This involves high storage costs, which has given rise to the development of a fast continuous method for the maturation of beer to substitute storage. In this method, the yeast is removed from the unmatured beer after the conventional main fermentation, the unmatured beer is subjected to a heat treatment (e.g. 80 - 90 °C for 5 - 15 min), whereupon the beer is cooled (e.g. 10 - 15 °C) and then matured in a reactor in which the yeast is immobilised on a carrier. Finally, the beer is finished, i.e. stabilised and filtered in the conventional manner. The retention time in the continuous reactor is of the order of e.g. two hours.

During the heat treatment, the  $\alpha$ -acetolactate contained in the unmatured beer is converted to diacetyl and partly also acetoin. The taste of diacetyl is felt in beer even when the acetyl concentration is only 0.05 mg/l. It is a strong sugary or taffy-like taste and flavour, which is characteristic of unmatured or newly brewed beer. In the reactor, the yeast reduces the diacetyl into acetoin. At the same time, certain other carbonyl compounds are also reduced, and the result is a savoury beer. Acetoin has a milder taste and flavour, and the threshold concentration, 50 - 1000 mg/l, above which its taste is felt in beer is considerably higher than for diacetyl.

Prior-art methods are described e.g. in the following articles: Monograph XXIV of the European Brewery Convention, E.B.C.-Symposium Immobilized yeast applications in the brewing industry, Espoo, Finland, October 1995 (ISBN 3-418-00749-X): E. Pajunen: Immobilized yeast lager beer maturation: DEAE-cellulose at Sinebrychoff (pages 24-40) and I. Hyttinen: Use of porous glass at Hartwall brewery in the maturation of beer with immobilized yeast (pages 55-56). In the for-

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mer application, the carrier used to immobilise the yeast is DEAE cellulose with titanium dioxide and polystyrene mixed in it; patent specification US 4915959 describes the same application. In the latter application, the carrier is porous glass. In the production of beer containing only a small amount of alcohol or no alcohol, a column in which yeast is immobilised in DEAE cellulose (H.Lommu: Immobilized yeast for maturation and alcohol-free beer, Brewing and Distilling International, May 1990, pp. 22-23) has been used.

These applications work well in a technical sense, and the beer produced is of good quality, the same as beer matured by the traditional method. However, the problem with the known applications is the high cost of the carrier materials. Purchase of the carrier material is a significant investment, and because of the high price the carrier must be regenerated after a certain period of use so that it can be used again.

In traditional maturation in a container, fairly large wooden strips e.g. 400 - 500 mm long and 40 - 50 mm wide have been added into the storage containers. The purpose of the strips is to bind some of the yeast and thus to promote the clarification, and to some extent, secondary fermentation of the beer. This is a conventional slow batch process. Some breweries still use this procedure, mainly to preserve the tradition.

In the production of ethanol by a continuous fermenting process, immobilisation of yeast has been effected by using pieces of wood, e.g. beech, (M. Moo-Young, J. Lamprey and C.W. Robinson: Immobilisation of yeast cells on various supports for ethanol production, Biotechnology Letters 2 (1980) No. 12, pp. 541-545) and birch (M.A. Gencer and R. Mutharasan: Ethanol fermentation in a yeast immobilised tubular fermentor,

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Biotechnology and Bioengineering 25 (1983) 2243-2262).  
However, the production of ethanol is completely different from the manufacture of beer: in the former, the aim is to achieve a fermenting process as effective as possible, whereas in the latter the primary objective is to develop the desired good taste and flavour in conjunction with the fermenting process.

In the production of beer, small-scale experiments have also been carried out in which wooden chips have been used in conjunction with main fermentation to immobilise yeast: J. Kronlöf and V.-P. Määttä: Main fermentation using immobilised yeast in beer production, Mallas ja Olut 1993, No. 5, pp. 133-147).

#### SUMMARY OF THE INVENTION

The object of the present invention is to eliminate the drawbacks mentioned above.

The object of the invention is to disclose a fast, continuous method for the maturation of beer, in which yeast immobilised on a carrier effectively reduces the diacetyl concentration to a level below an acceptable taste threshold and which is applicable for use in conjunction with known beer production methods for the maturation of unmaturred beer.

Another object of the invention is to disclose a fast, continuous method for the maturation of beer in which the carrier is an economically priced and risk-free material.

A further object of the invention is to disclose a continuous maturation reactor for implementing the method.

<sup>30</sup>  
155 A, ~~The method of the invention for the maturation of beer is characterised by what is presented in claim 1.~~  
~~THE CLAIMS~~

<sup>35</sup> The maturation reactor of the invention is characterised by what is presented in ~~claim 13.~~  
~~THE CLAIMS~~

The invention is based on research work carried out, the aim of which was to apply the technique

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of immobilising yeast to secondary fermentation and maturation of beer. It was unexpectedly established that wooden particles and/or similar particles are excellently suited for use as a carrier for the immobilisation of yeast.

In the continuous method of the invention for the maturation of beer, the unmaturred beer, after the removal of yeast and a heat treatment, is passed into a bio-reactor filled mainly with wooden particles and/or similar particles with yeast immobilised on them. The principle of the method of the invention is the same as in industrial procedures using DEAE cellulose or porous glass as a carrier. The yeast removal and other secondary treatment operations are performed as in the known procedures.

The method of the invention is applicable for the production of various kinds of beer, i.e. bottom yeast beer and scum yeast beer. Suitable raw materials are malt and other sources of starch and sugar as are known in beer production. The beer to be produced may have an alcoholic content between 0 - 10 % and a pitching wort content between 5 - 20 % or more, even 30 %.

In the method of the invention, the carrier may consist of wooden particles and/or similar particles of any size and shape, preferably cut into fairly small chips, sticks or into the shape of any regular or irregular bodies of roughly uniform size. The largest dimension of the particles is mainly 1 - 100 mm, advantageously 1 - 50 mm and preferably 2 - 20 mm.

The wooden particles to be used may be produced from any deciduous wood species, e.g. aspen, beech, palm or the like. The particles may also be produced from coniferous wood. The wood species to be used can be so chosen that the aromatic substances contained in it will have a desired effect on the taste and flavour of the beer to be produced. The par-

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ticles may also be produced from tropical grass, e.g. bamboo, rattan and/or the like.

In the continuous reactor, some of the yeast is immobilised on the carrier and some of it may be freely suspended. Conventional known brewing yeasts are well suited for use in such a reactor. However, if highly flocculable yeasts are used, a high yeast concentration will be quickly reached in the reactor, and the high yeast concentration is also maintained, thus improving the efficiency of the reactor.

The immobilisation of yeast can be implemented in any known way, e.g. as described in patent specification ~~US 4915959~~.

The amount of immobilised yeast in the reactor may vary as is known in the art, a preferable amount being  $10^6$  -  $10^9$  yeast cells/ $1\text{ cm}^3$  of filler particles. The service life of the wooden particles used for yeast immobilisation is a few months, e.g. 1 - 6 months, but it may be as long as 1 year or more.

The rate at which the unmaturred beer flows through the reactor and its retention time in the reactor have an effect on the diacetyl content of the beer. The flow rate of the unmaturred beer is adjusted to a value such that a sufficient amount of diacetyl is reduced to acetoin in the reactor, with the result that the diacetyl concentration in the matured beer does not exceed an acceptable taste threshold. The flow rate of unmaturred beer through the reactor may be 0.05 - 2 times the reactor volume / h. A preferred flow rate of unmaturred beer is of the order of 0.5 - 1 reactor volume / h. The temperature in the reactor is 5 - 22 °C, preferably 5 - 20 °C. Even higher temperatures may be used.

The maturation reactor may be pressurised to maintain the carbon dioxide in a dissolved state in the reactor. Free carbon dioxide may hamper the operation of the reactor. The operation pressure can be se-

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lected according to temperature, desired taste and beer quality.

After the maturation, the beer can be cooled to a desired stabilising temperature, and secondary treatment of the beer, such as stabilising, filtering and decanting, can be implemented in a manner known in itself.

Because of their low price, the wooden particles and/or similar particles used as filler may be thrown away after use. Disposal of the particles is easy and free of risks. The filler may also be regenerated after use, e.g. by treating them with hot water or vapour, by washing or by some other suitable treatment.

15 If desirable, the wooden particles and/or similar particles used as filler can be subjected to a treatment prior to immobilisation. The particles can be e.g. washed or treated in some other way as desired.

20 The continuous maturation reactor of the invention is an upright column in which the liquid flows through the column from bottom to top or from top to bottom. The diameter of the reactor is of the order of  $1.5 \pm 1 - 2.5 \pm 1$  m and its height is of the order of  
25  $2.5 - 10$  m. The column may be provided with one or more sieves, intermediate bottoms or flanges to keep the filler particles in the reactor. The column is filled mainly with wooden particles and/or similar particles with yeast immobilised on them.

30 AS compared with prior art, the advantages of the invention are based on the use of a cheaper carrier material, which gives the same final result as more expensive carrier materials.

The low price of the wooden particles and/or similar particles also makes it unnecessary to regenerate the particles. When expensive carriers are used, regeneration is necessary to prolong the service life

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of the carrier. Regeneration causes direct and indirect additional costs.

Wood and/or similar material also has the advantage that, being a natural material, it is free of risks.

The invention will now be described in detail via the following examples.

#### EXAMPLE 1

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##### Test arrangements:

Räuchergold KL1 beech chips (5 litres) were cooked in ion-exchanged water (5.5 litres) for an hour. The water was removed and the chips were cooked for 4 hours in ethanol containing 10 % alcohol by volume. The alcohol solution was removed and finally the chips were cooked for 1 hour in ion-exchanged water.

The reactor was filled with the wet chips up to the 5.1 l mark. The reactor was assembled and autoclaved at 121 °C for 21 minutes together with the connections and hoses. After cooling, 3 litres of yeast suspension was pumped into the reactor in 6 hours by using a hose pump. Air was supplied into the reactor at the rate of 50 ml/min and wort at the rate of 100 ml/h overnight at 20 °C. After this, the supply of materials was stopped and the reactor was cooled to 10 °C.

The unmaturred beer fed into the process was unmaturred beer produced via immobilised main fermentation, in which the total content of visinal diketones was about 0.8 - 0.3 mg/ml. After the main fermentation, the unmaturred beer was filtered through Seitz K filter paper into an autoclaved (121 °C, 20 min) restaurant container, which was used as a supply container for the secondary fermentation reactor.

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#### Description of the process:

The process comprises heat treatment of unma-  
tured beer, its cooling to 10 °C, secondary fermenta-  
tion (maturation) with immobilised yeast, and recep-  
5 tion of the product.

From the supply container, the unmaturred beer  
is pumped into heat treatment using a diaphragm pump  
(Prominent Mini Gamma). The heat treatment (80 °C,  
about 60 min) takes place in a thin-walled metal re-  
10 tention pipe immersed in a water bath at about 80 °C.  
The beer removed from the heat treatment flows into a  
cooling jacket made of glass, where it is cooled to  
the secondary fermentation temperature of 10 °C. The  
cooled beer flows through the reactor from bottom to  
15 top. From the top of the reactor, the beer flows via a  
separating funnel into a receiving container. The re-  
ceiving container used is a 50-l restaurant container.

#### Analyses:

20 From the unmaturred beer fed in, from the heat  
treated unmaturred beer and from the post-fermented  
beer, the total amounts of visinal diketones (total  
VDK), free diketones (free VDK), aromatic substances  
and apparent extract concentration were analysed. The  
25 retention time in the reactor was estimated based on  
the flow rate. In addition, the beer colour was ana-  
lysed twice during the test period.

#### Results:

30 The retention times in the reactor are pre-  
sented in Table 1. With the reactor filled up to the  
5.1 l mark, the liquid volume in the reactor was 3.6  
litres. The internal amount of liquid within the  
chips, which is very small as the chips are wet all  
35 the time, was not taken into account, nor was the liq-  
uid remaining on the surface of the chips.

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free pentanedione	0.07	0.10	<0.01	
total VISINAL DIKETONES	0.32	0.33	<0.03	90.6

Table 3. Concentrations of visinal diketones (mg/dm<sup>3</sup>) and their conversion (%) at flow rate 300 ml/h.

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1. determination	Supply	Heat treated	Post-fermented	Conversion
total diacetyl	0.28	0.27	0.01	96.4
free diacetyl	0.17	0.27	0.01	94.1
total pentanedione	0.14	0.13	0.01	92.9
free pentanedione	0.07	0.12	<0.01	
total VISINAL DIKETONES	0.42	0.40	0.02	95.2
2. determination				
total diacetyl	0.39	0.37	0.02	94.9
free diacetyl	0.23	0.39	0.02	91.3
total pentanedione	0.22	0.19	0.01	95.4
free pentanedione	0.11	0.18	<0.01	
total VISINAL DIKETONES	0.61	0.56	0.03	95.1

Table 4. Concentrations of visinal diketones (mg/dm<sup>3</sup>) and their conversion (%) at flow rate 400 ml/h.

	Supply	Heat treated	Post-fermented	Conversion
total diacetyl	0.46	0.41	0.07	94.8
free diacetyl	0.27	0.38	0.06	77.8
total pentanedione	0.19	0.16	0.01	94.7
free pentanedione	0.09	0.14	0.01	88.9
total VISINAL DIKETONES	0.65	0.57	0.08	87.7

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